Indian J. Phys. **69A** (2), 295 – 298 (1995)

I J P A
an international journal

Estimation of total charge changing cross section in ^{197}Au + ^{27}Al interactions at 0.930 GeV/n

D P Bhattacharyya, S Saha, Basudhara Basu, Pratibha Pal, Ruma Rakshit, Rena Majumdar and Mala Mitra

Department of Theoretical Physics, Indian Association for the Cultivation of Science, Jadavpur, Calcutta-700 032, India

and

S Biswas

Cosmic Ray and Space Physics Division, Tata Institute of Fundamental Research, Colaba, Bombay-400 005, India

Received 23 December 1994, accepted 18 January 1994

Abstract : The total charge changing cross section of ^{197}Au projectiles at BEVALAC energy 1.015 GeV/n in ^{27}Al target has been studied using a stack consisting of CR-39 (DOP) plastic track detectors and the target. The measured total cross section for Au + Al interactions has been found comparable with the extrapolated BEVALAC data of Binns *et al* and our earlier results on ^{238}U-ions in ^{27}Al target at relativistic energies. The estimated value of the total charge changing cross section has been found to be (3150 ± 134) mb which is close to the expected result from the fit after Binns *et al*.

Keywords : Au + Al interactions, BEVALAC beam, total charge changing cross section

PACS Nos. : 25.75.+r, 96.40.De

The study of nuclear interaction phenomena at relativistic energies is necessary for understanding the heavy ion projectile interactions with nuclear matter under conditions of high pressure and temperature.

The comparison of the observed data on nucleus-nucleus interactions with the expected result yield the interaction picture of the hadron structure. An accurate information on the fragmentation cross section in nucleus-nucleus interactions is important for understanding the ultra heavy nuclei composition of cosmic rays. This may exhibit some idea on the galactic cosmic ray exposure behind the shielding in the space flight pointed out earlier by Townsend [1].

In the present work, we have used CR-39 (DOP) solid state nuclear track detector to determine the total charge changing cross section for the production of fragments of charge Z_F in collisions of ^{197}Au beam at 0.930 GeV/n detected on the CR-39 (DOP) stack after traversing 2 cm thick ^{27}Al target sandwitched between CR-39 (DOP) sheets. Frequencies of the etch pit cones of the ^{197}Au projectiles in the plastic plates both above and below the Al target have been measured to estimate the total charge changing cross section and the result has been compared with the experimental results of Binns *et al* [2] for Kr, Xe, Ho and Au along with ours for U interactions with Al target [3]. The expected results from the fit after Dudkin *et al* [4] have also been considered in the present survey.

Table 1. Fluence of Au projectiles incident at energy 0.930 GeV/n on a 2 cm ^{27}Al target sandwitched by CR-39 (DOP) plastic sheets and of those emerging through it at energy 0.717 GeV/n

Incident projectile charge Z	Number of Au nuclei incident on the target (per cm^2)	Number of Au nuclei emerging from the target (per cm^2)	Total mean free path of the Au projectiles in Al λ_I (g/cm^2)	Total charge changing cross-section σ_T (mb)
79	4018	2749	14.22 ± 0.94	3150 ± 134

We used CR-39 (DOP) Pershore plastic plates with thickness of about 450 μm and of area 25 cm^2 each and a $^{27}_{13}$Al target, 2 cm thick. There are 10 sheets of plastics above the target and 5 sheets below it. The stack was irradiated at an angle 30° with the $^{197}_{79}$Au nuclei at 1.015 GeV/n energy from the Lawrence Berkeley Laboratory BEVALAC. The energies of the surviving $^{197}_{79}$Au nuclei were estimated and found to be 930 MeV/n and 717 MeV/n at the top and the bottom of the target respectively. The sheets were etched for 3 hours in 6.25 N NaOH solution at (70 ± 0.1) C. The bulk etch rate (V_G) of the plastic material was found to be of value (1.36 ± 0.05) μm/h. The cone lengths of the etch pits on both the surfaces of the plastic plates above and below the target, were measured by a Leitz microscope with a X15 filar micrometer eyepiece and a X24 dry objective. The finest division of the filar micrometer scale was 0.3 μm. Frequencies of the etch pit cones corresponding to only Au projectiles, were measured on the same two plates and the results were analysed to determine the total charge changing cross section. The number of cones per cm^2 of ultra heavy ions in the plastics adjacent to the 2 cm Al target are displayed in the Table 1. The measured cone length distribution of the Au projectiles of $Z/\beta = 95.7$ in the plate just adjacent down to the target has been used to calculate the charge sensitivity (V_T/V_G) of the CR-39 (DOP) solid state nuclear track detector. The response V_T/V_G of the CR-39 (DOP) plastic detector for Au-ion detection has been found to be 41.69 for $Z/\beta = 95.7$ which is comparable to the result as expected from the global survey displayed in Figure 1. The fit to the global data [3,5–9] as displayed in the figure follows an exponential relation of the form

$$V_T/V_G = A \exp\,[B(Z/\beta)], \tag{1}$$

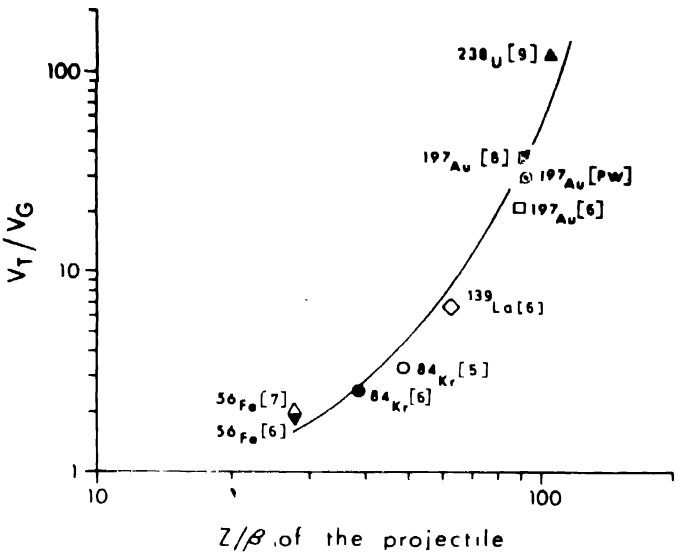

Figure 1. The etch rate distribution V_T/V_G has been displayed as a function of Z/β for VH ions in CR-39 detectors. ○ - 0.45 GeV/n ^{84}Kr in CR-39 (MA ND) Bhattacharyya *et al* [5], ▼ - 1.70 GeV/n ^{56}Fe, ● - 1.45 GeV/n ^{84}Kr, ◇ - 1.28 GeV/n ^{139}La, □ - 1GeV/n ^{197}Au in CR-39 (DOP) Salamon *et al* [6], ◆ - 1.88 GeV/n ^{56}Fe in CR-39 (DOP) Bhattacharyya *et al* [7], ■ - 1.015 GeV/n ^{197}Au in CR-39 (DOP) Bhattacharyya *et al* [8], ▲ - 0.927 GeV/n ^{238}U in CR-39 (DOP) Bhattacharyya *et al* [9], ⊕ - 0.930 GeV/n ^{197}Au in CR-39 (DOP) Present Work. Full curve shows the exponential fit to the data obtained from global survey for different projectiles in CR-39 detector.

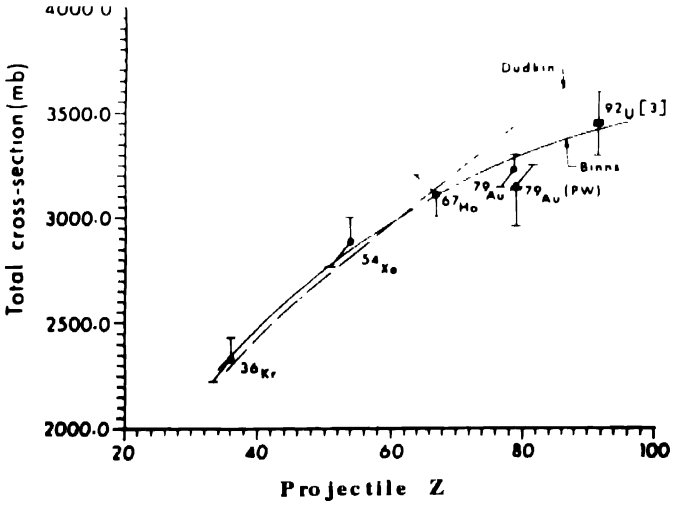

Figure 2. Total charge changing cross section in Al target is plotted as a function of projectile charge. ● - 1.419 GeV/n ^{84}Kr, 1.155 GeV/n ^{131}Xe, 1.022 GeV/n ^{165}Ho, 0.932 GeV/n ^{197}Au Binns *et al* [2], ■ - 0.927 GeV/n ^{238}U Bhattacharyya *et al* [3], ▲ - 0.930 GeV/n ^{197}Au present work. Full and broken curves are the expected results from the fits after Binns *et al* [2] and Dudkin *et al* [4] L, respectively.

where the numerical values of the fitting parameters are found to be $A = 0.405114$ and $B = 0.048554$, respectively. The total cross section for the Au + Al interactions has been estimated from the measured number of tracks per cm^2 in the plastic sheets adjacent to the Al target. Table 1 shows the detail of the cone length frequency measurements for the estimation of the mean free path of Au in Al target at 930 MeV/n energy. The estimated total charge changing cross-section has been compared with the empirically fitted results of Binns *et al* [2] along with our earlier result with U + Al interactions [3] The emperically fitted results of Dudkin *et al* [4] are also displayed in the Figure 2. It is evident from the plot that the total charge changing cross section of ultra heavy nuclei has a projectile charge dependence for a particular target.

Acknowledgment

The authors are thankful to Prof. H J Crawford and Lawrence Berkeley BEVALAC group for providing beam exposure facility for the present experiment.

References

[1] L W Townsend *NASA Techn Memorandum* **4386** (1992)

[2] W R Binns, T L Garrard, M U Israel, M P Kertzmann, J Klarmann, E C Stone and C J Waddington *Phys Rev* **C36** 1870 (1987)

[3] D P Bhattacharyya, R Rakshit, B Basu, P Pal, S Biswas and N Durgaprasad *Nuovo Cim* **15C** 341 (1992)

[4] V E Dudkin, E E Kovalev, N A Nefedov, V A Antonchik, S D Bogdanov, V F Kosmach, A Yu Likhachev, J Hassan, E V Benton and H J Crawford *Nucl Phys* **A568** 906 (1994)

[5] D P Bhattacharyya, B Basu, P Pal, R Rakshit, S Chakrabarty and I Hunyadi *Nuclear Instrum Meth* **B61** 197 (1991)

[6] M H Salamon, P B Price, M Tincknell, Shi Lin-Guo and G Tarle *Nuclear Instrum Meth* **B6** 504 (1985)

[7] D P Bhattacharyya, B Basu, P Pal, R Rakshit, S Chakrabarty, S Biswas and N Durgaprasad *Nuovo Cim* **15C** 11 (1992)

[8] D P Bhattacharyya, S Chakrabarty, R Rakshit, B Basu, P Pal and S Biswas *Nucl Instrum Meth* **B73** 308 (1993)

[9] D P Bhattacharyya, R Rakshit and P Pal *FIZIKA* (in press) (1995)